Constraining the evolution and origin of methane plumes on Mars

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Constraining the evolution and origin of methane plumes on Mars

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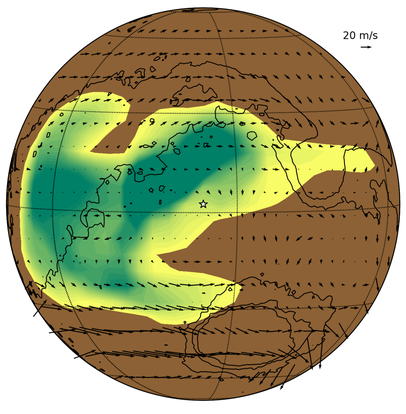
1. Introduction

- The first ever methane vertical profiles retrieved by NOMAD [1] and ACS on the ExoMars Trace Gas Orbiter mission will require interpretation to identify the sources and sinks related to methane on Mars (is it created by life or not?)
- This study [2] tracks the vertical evolution of methane from three different emission scenarios, using a Global Circulation Model (GCM)

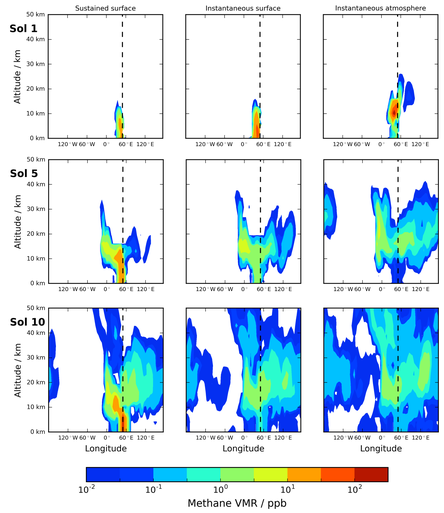
2. Model and simulations setup

- Methane plumes are tracked in 3-D space and time using the UK version of the LMD GCM, which includes a UK-only spectral dynamical core [3] and semi-Lagrangian advection scheme [4]



Tracking methane evolution in the GCM. Arrows indicate wind direction and the location of release is denoted by the star symbol.

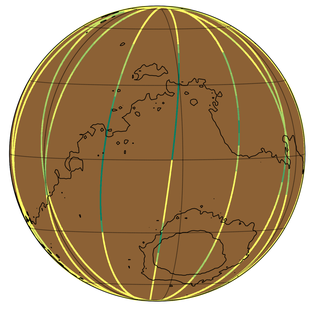
- Best estimate for winds that transport methane by combining GCM with temperature profiles using Analysis Correction scheme [5]
- Area (50°E, 2.5°N) and timing of methane release to coincide with the plume observed in 2003 [6]
- Three different emission scenarios: **Sustained** (surface methane release over whole time period), **Instantaneous** (surface methane release for a single timestep) and **Instantaneous atmosphere** (atmospheric methane release (10 km) for a single timestep)



Meridional cross section of methane vertical profile at 2.5°N. Black dashed line indicates longitude of emission.

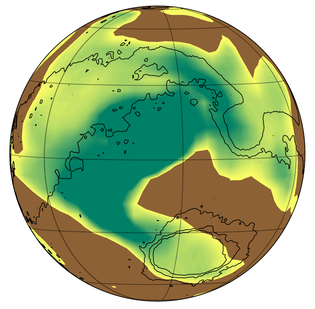
3. Evolution of methane over source location

- For clues to the origin and source of methane plumes we determine timescales on which the three emission scenarios can be distinguished from one another
- To discriminate between a sustained or instantaneous surface emission (at methane release rates constrained by previous observations and modelling studies), requires at least 10 sols of tracking the emission
- To determine if the initial methane source was from destabilisation of metastable methane clathrates (i.e. atmospheric), a methane release must be observed within 5 to 10 sols of the initial emission



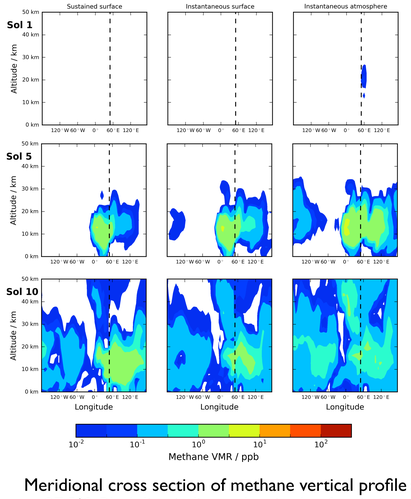
Left: sample pattern of the observations to be taken by the NOMAD and ACS instruments on the ExoMars Trace Gas Orbiter mission

Right: Ability to provide best estimate of global methane distribution utilising tracking capabilities of a GCM to see how a methane plume evolves



4. Vertical evolution of methane away from source location

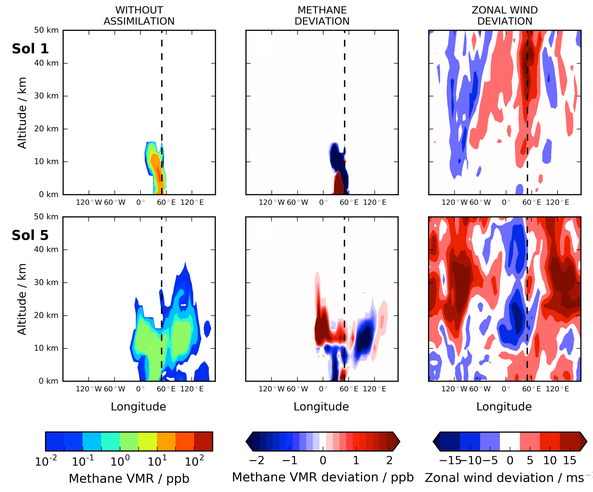
- In case of nearby observations in time not located directly over the source emission, we also investigate vertical profile of methane away from initial source location
- Stronger high altitude meridional winds result in an initially atmospheric methane source being spread further in latitude after one sol
- It would be difficult to know if the original methane source was released at the surface after 5 sols (away from the source location) since there is a lack of methane below 5 km at the source longitude in all three different scenarios



Meridional cross section of methane vertical profile at 27.5°S. Black line indicates longitude of emission.

5. Impact of thermal data assimilation

- Alterations to local wind patterns and deviations in the evolution of a modelled methane plume are seen when combining thermal profiles with the GCM
- To backtrack and localise the source of methane, which will give clues to its origin, it is critical to provide the most accurate wind field to transport methane in the martian atmosphere



Meridional cross section of methane vertical profile at 2.5°N without assimilation (left), deviation of methane (middle) and zonal wind (right) from assimilation. Black dashed line indicates longitude of emission.

6. Summary

- **Tracking of a methane plume is vital for determining unknown sources/sinks of methane**
- **Identifying destabilisation of methane clathrates as the source of methane requires observing the plume within the first 5 to 10 sols of emission**
- **Assimilation of thermal data is critical for correct backtracking of a methane source to its origin**

References

[1] Vandaele, A. C. et al., Planet. Space Sci., **119**, 233-249, 2015 [2] Holmes, J. A. et al., Geophys. Res. Lett., **44**, 8611-8620, 2017 [3] Hoskins, B. J. and Simmons, A. J., Quart. J. Royal Meteorol. Soc., **101**, 637-655, 1975 [4] Newman, C. E. et al., J. Geophys. Res., **107**, 5123, 2002 [5] Lewis, S. R. et al., Icarus, **192**, 327-347, 2007 [6] Mumma, M. J. et al, Science, **323**, 1041-1045, 2009

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